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(54) TUBE AND CYLINDRICAL SURFACE SEALING APPARATUS

(71) We, PRESSURE SCIENCE INCORPORATED, a corporation organised and existing under the laws of the State of Maryland, United States of America, of 11642 Old Baltimore Pike, Beltsville, State of Maryland 20705, United States of America do hereby declare the invention for which we pray that a patent may be granted to us and the method by which it is to be performed to be particularly described in and by the following statement:

The present invention relates to a fluid-tight sealing apparatus for sealing a tube to a cylindrical surface, where the tube and cylindrical surface are likely to be subjected to axial, rotational and angular misalignment and/or movement.

Various piping systems having fluid under pressure flowing therethrough must generally be designed to provide for some degree of flexibility to allow for dimensional tolerances, thermal expansion and contraction, and vibrational deflections between the various components which are connected by the piping. Lightweight compact means, which are particularly desirable in aircraft and missible systems, for providing such flexibility are known in the prior art; however, these prior art devices generally employ elastomeric, plastics, rubber or asbestos type seals to prevent leakage of the fluid flowing in the flexible system. Unfortunately, these types of seals tend to fail when exposed to high temperatures (above 400°F.-500°F.) at very low temperatures, or in environments subjected to radiation.

Typically, sealing assemblies used in flexible piping systems in environments beyond the capability of seals made of elastomers and the like employ sections of piping with circumferential corrugations (i.e., bellows) expansion loops, or devices containing piston rings. However, these devices are generally very heavy, require large amounts of space, and are prone to failure and, therefore, leakage due to fragility and wear. Moreover, these sealing systems often require exact tolerances and are difficult to manufacture and install.

According to the present invention, there is provided a fluid-tight sealing apparatus for sealingly connecting a tube to a cylindrical surface where the tube and the cylindrical surface are likely to be subjected to relative angular misalignment, axial movement and rotation, the apparatus comprising an annular metallic, resilient sealing member comprising a tapering portion and a ring portion which is integrally and coaxially connected to one end of the tapering portion so that the ring portion and the tapering portion are located on opposite sides of a radial plane containing said one end of the tapering portion, the sealing member being coaxially connected, when in use, to the end of a tube so that the tapering portion is disposed between said end of the tube and said ring portion, the ring portion having a curved surface which has a free diameter as herein defined which is different from the diameter of the cylindrical surface whereby when the sealing member is connected to the cylindrical surface so that the curved surface of the ring portion contacts said cylindrical surface, said ring portion is elastically deformed to produce an interference fit between the curved surface of the ring portion and said cylindrical surface which constitutes a fluid-tight seal therebetween.

The cylindrical surface may be the interior surface of a bore with the sealing member including a frustoconical portion having a ring portion at the larger end thereof and fitting into the bore. In this instance, the free diameter of the curved surface prior to installation is greater than the interior diameter of the bore and, since the sealing member is resilient, the curved surface provides a spring loaded interference fit be-

tween itself and the bore.

Alternatively, the cylindrical surface may be the exterior surface of a conduit with the sealing member including a frustoconical portion having the ring portion at the smaller end thereof and fitting around the conduit. In this instance, the curved surface has a free diameter prior to installation which is less than the outer diameter of the conduit, thereby providing a spring loaded interference fit between the curved surface and the outer surface of the conduit.

Whilst the radius of curvature in longitudinal section of the curved surface of the ring portion which contacts the cylindrical surface, may be equal to the radius of the cylindrical surface, it has been found that a smaller radius of curvature in longitudinal section of the curved surface can reduce the leakage rate of the sealing apparatus. That is, since leakage of fluid between two contacting surfaces is related to the contact stress, which is defined by the force tending to push the contacting surfaces together divided by the area of contact, an increase in the contact stress reduces leakage. Thus, by making the radius of curvature in longitudinal section of the curved surface on the ring portion smaller, the area of contact is reduced, thereby increasing the contact stress.

In addition, by decreasing the radius in longitudinal section of the curved surface, exact tolerances and/or very high polish on the contacting surfaces are not necessary.

Moreover, since the sealing apparatus is formed of metal, it can exist under extreme temperatures and in environments subjected to radiation.

Since the frustoconical tapering portion and the ring portion are preferably made of very thin, high strength alloys, the sealing member can be compact and light in weight.

Additionally, the difference in diameters of the tube and the cylindrical surface to be coupled is such that, while an interference fit is utilized, the dimensions and materials are chosen so that the elastic limit of the sealing member is not exceeded so that it will return to its initial size after the tube and the cylindrical surface are disconnected. Thus, the sealing member is reusable.

As used herein, the phrase "interference fit" means that because the curved surface of the ring portion has a free diameter prior to installation slightly different from the diameter of the cylindrical surface, and since the curved surface is resilient, the forcing of the curved surface into or around the cylindrical surface causes the ring portion of the sealing member to be elastically deformed and thus maintained in intimate circumferential sealing contact with the cylindrical surface due to the reactive force of the elastic deformation.

As used herein, the phrase "free diameter" means the diameter of the ring portion curved surface prior to installation with the cylindrical surface, and therefore prior to its elastic deformation, whether compression or expansion.

Reference is now made to the accompanying drawings which illustrate, by way of example, embodiments of the present invention and of which:

Figure 1 is a side elevational view in longitudinal section of a tube having a fluid-tight sealing apparatus thereon in accordance with the present invention, the apparatus being in its elastically undeformed state;

Figure 2 is a side elevational view in longitudinal section of the tube shown in Figure 1 in its elastically deformed state in which it has been installed in the cylindrical bore of a body, the bore having a diameter of X which is less than the free diameter A of the apparatus shown in Figure 1;

Figure 3 is an end elevational view in section taken along lines 3-3 in Figure 2 showing a keeper assembly which prevents the sealing member from exiting from the cylindrical bore in the body shown in Figure 2;

Figure 4 is a side elevational view in longitudinal section similar to Figure 2 except with the tube angularly misaligned relative to the centre line of the cylindrical bore in the body;

Figure 5 is a side elevation view in partial section showing a tube having a fluid-tight sealing apparatus at both ends, these two ends being received in two bodies having cylindrical bores therein and maintained in that position by means of keeper assemblies;

Figure 6 is a side elevational view in partial section of a tube having two fluid tight sealing apparatus at opposite ends, these ends being received in two bodies having cylindrical bores therein, but the use of the keeper assemblies, being unnecessary is eliminated;

Figure 7 is a side elevational view in longitudinal section of a second embodiment of the present invention in which the cylindrical surface is the exterior surface of a cylindrical conduit and the sealing member fits around the cylindrical conduit;

Figure 8 is a side elevational view in longitudinal section showing the assembly of Figure 7 in which the two conduits shown therein are misaligned; and

Figure 9 is the same as Figure 2 except the ring portion curved surface has a radius of curvature equal to X/2.

Referring to Figure 1, a fluid-tight sealing apparatus in accordance with one embodiment of the present invention includes a sealing member 10 at the end of a tube 12, the sealing member comprising a ring portion 14, a frustoconical elongate tapering portion 16,

a frustoconical short portion 18 and a cylindrical portion 20. These elements comprising the sealing member 10 are integrally formed and, as shown in Figure 1, the cylindrical portion 20, which has the same outer diameter as the tube 12, is welded along weld line 22 to the end of the tube 12. The other end of the cylindrical portion 20 is integral with the smaller end of the frustoconical short portion 18 which has its larger end integral with the smaller end of the frustoconical tapering portion 16. The larger end of the tapering portion 16 is integral with the ring portion 14 which is at the end of the sealing member 10, and which is located on the other side of a plane containing the larger end of the tapering portion.

The thickness x of the cylindrical wall forming the cylindrical portion 20 can be the same or different from the thickness of the cylindrical wall forming the tube 12. As seen in Figure 1, the thickness of the wall forming the sealing member 10 decreases along the frustoconical short. portion 18 from the thickness x to a thickness t which continues substantially the same along the wall forming the frustoconical tapering portion 16 and the ring portion 14. Thus, the ring portion and the tapering portion have substantially equal longitudinal cross-sectional thicknesses. This reduction in thickness from x to t enhances the resiliency of the sealing member 10. The thickness can be from 0.003 to 0.020 inch in the range of tube diameters from 0.125 to 15.00 inches with the material forming the sealing member 10 comprising a high strength alloy such as "Inconel" 718 or "Waspaloy" (both "Inconel" and "Waspaloy" are Registered Trade Marks) which have excellent spring properties at extreme temperatures, and which are both definable as high strength nickel base austenitic precipitation hardenable alloys.

The ring portion 14 has an outer curved surface 24 and is arcuate in longitudinal cross-section. The exterior free diameter A (as defined above) of the curved surface 24 of the ring portion 14 is greater than the diameter X of a cylindrical bore 26 in a body 28 shown in Figure 2. Sealing between the member 10 and the cylindrical bore 26 when the member 10 is inserted into the cylindrical bore 26 is provided by the intimate spring loaded contact between the curved surface 24 and the surface of the bore 26 which is a cirumferential contact line at the seal interface 30 (Figure 2).

Referring again to Figure 1, the curved surface 24 of the ring portion extends outside the frustoconical containing the outer surface of the frustoconical tapering portion 16, and therefore, the diameter A of the ring portion 14 is greater than the maximum diameter of the frustoconical elongate portion 16.

Referring now to Figure 2, the tube 12 with the sealing member 10 thereon is shown as being fitted, or installed into the cylindrical bore 26 in the body 28, such body being, for example, a port on a valve, actuator or similar component formed of metal or ceramic material and the tube 12 being a pipe or conduit having fluid under pressure flowing therethrough and into or out of the body 28. The fit of the sealing member 10 with the cylindrical bore 26 is an interference fit as defined above insofar as the maximum free diameter A of the curved surface 24 is greater than the inner diameter X of the cylindrical bore 26 and the sealing member 10 has therefore been forced into the cylindrical bore, remaining there by means of the outwardly directed spring force of the resilient ring portion 14 and the resilient tapering portion 16.

As shown in Figure 2, the curved surface 24 contacts the inner surface of the cylindrical bore 26 along the seal interface or contact line 30 which extends circumferentially around the curved surface 24 where it continuously contacts the inner surface of the cylindrical bore 26, thereby providing the seal between these two elements.

The interference fit must be relatively light to enable the sealing member 10 to be inserted or removed by normal hand pressure and to ensure that the resilient sealing element is not stressed beyond its elastic limit. This relatively light interference fit, which keeps friction forces low, permits relative sliding and rotation of the sealing member 10 and bore 26 whilst they are in sealing contact. Although the interference fit is relatively light, good sealing characteristics are present since the pressure of the fluid in the tube and the bore tends to force the sealing member outwardly into its sealing contact, thereby making the seal "pressure energized". With a cylindrical bore diameter X of 0.420 to 0.422 inch, a free diameter A of the curved surface 24 of 0.424 to 0.425 inch (i.e. the interference fit is 0.002-0.005 inch) has been found advantageous for a seal of this diameter (0.421 inch). Two inch diameter seals work well with a 0.003 to 0.007 inch interference fit.

The contained pressure in the tube being sealed would, in most applications greater than pressures of about 1 psi, be sufficient to blow the sealing member 10 out of the bore 26.

Consequently, a keeper assembly 32, shown in Figures 2, 3, 4, and 5 is utilized to prevent the sealing member 10 from exiting the cylindrical bore 26. As best seen in Figures 2 and 3, this keeper assembly 32 comprises a main member 34 having a cutout 36 therein, the main member 34 being coupled to the surface 40 of the body 26 adjacent the entrance 42 of the cylindrical bore 26 by

means of a bolt 38 passing through an aperture 44 therein and being received in threaded bore 46 in the surface 40 of body 28.

The keeper assembly 32 is coupled to the body 28 after the sealing member 10 has been manoeuvred into the cylindrical bore 26 by manoeuvring the cutout 36 over the cylindrical portion 20 and passing bolt 38 through aperture 44 into threaded bore 46.

As shown best in Figures 2 and 3, the maximum dimension of the cutout 36 is less than the maximum diameter of the frustoconical short portion 18 so that, when the tube 12 experiences a force tending to pull it axially out of the cylindrical bore, the main member 34 around the cutout 36 prevents such axial exiting by contacting the frustoconical short portion 18.

Referring now to Figure 5, a curved tube 48 is shown having a respective sealing member 10 such as that illustrated in Figure 1 in accordance with the present invention at each of its ends the sealing members 10 being received respectively in a body 28 and a body 50. Since the pressure of fluid flowing through curved tube 48, as indicated by the arrows, would possibly tend to pull the curved tube 48 from bodies 28 and 50, a respective keeper assembly 32 is utilized on each of the bodies 28, 50. As shown the sealing members 10 are integrally formed with the curved tube 48 so that the cylindrical portion 52 adjacent to the frustoconical short portion 18 of each member 10 is integral with the tube and therefore need not be welded thereto.

Referring now to Figure 6, bodies 54 and 56 are shown as having cylindrical bores 58 in which are accommodated respective sealing members 60 and 62 located at opposite ends of a tube 64. Each of the cylindrical bores 58 leads to a reduced diameter bore 59, each of which is adjacent to the respective end of tube 64. In this instance, if the bodies 54 and 56 are rigidly supported against relative movement and fluid flows through tube 64 in the direction shown by the arrows, there is no necessity for any keeper assemblies since there is no tendency for tube 64 to be axially displaced from the cylindrical bores 58 because any slight axial displacement of the tube 64 causes one end of the tube 64 to strike the face of the respective bore 59 before the other end of the tube 64 exits from the other body. With the removal of the necessity for any keeper assemblies, there is no need for the sealing members 60 and 62 to have frustoconical short portions like the portion 18 of Figure 1 interposed between the cylindrical portion 20 and the frustoconical tapering portion 16.

As seen on the right hand side of Figure 6, sealing member 60 has its cylindrical portion 20 welded along weld line 22 to the tube 64, while as seen on the left hand side of Figure 6, the sealing member 62 is integrally formed with tube 64, thereby eliminating the necessity of a weld line.

In practice, because of tolerances and deflections of the components such as bodies 54 and 56 in Figure 6 to be connected, the sealing member 10 may not be in perfect alignment with the cylindrical bore 26 as shown in Figure 2, but will tend to be misaligned by some angle a as shown in Figure 4. In general the tolerance and deflections are such as to require angle a to be less than 6° and most applications are covered by angle a being less than 12°.

As shown in Figure 4, the radius of curvature Y of the longitudinal section of the curved surface 24 is less than the radius of the cylindrical bore 26, i.e., less than X/2 which increases the contact stress between surface 24 and bore 26, thereby decreasing the leakage rate of the contained fluid. It has been found that the radius of curvature Y can be reduced to about 20% of the radius of the bore 26 and still maintain a "bubble tight" seal with Nitrogen at 500 psi for angles a of misalignment as great as 5° with a 0.3125 diameter tube. A "bubble tight" seal is one which has a leakage rate of 10^{-3} cc/sec. of Helium.

The high contact stress resulting from the reduced radius of curvature gives excellent leakage control at relatively small values of angles a but if larger values of angle a are required then the radius of curvature can be increased to meet such requirements, although a slight loss in leakage control may be experienced at small angles. Thus, on a 2.25 inch diameter seal, the pivotal capability of the sealing element (i.e. the variation possible in the value of angle a) can be increased from an angle $a=3°$ to $a=5°$ by changing the radius of curvature of the outer surface from 0.125 to 0.250 inch.

Whilst the circumferential seal interface 30 in Figure 2 would be substantially a circular line with the axis of the ring portion (i.e. of curved surface 24) and the axis of bore 26 being coincident (i.e. $a = 0$) in the arrangement of Figure 4 the seal interface becomes substantially an elliptical line with the axes of the tube 12 (i.e. of curved surface 24) and bore 26 out of alignment (i.e. the angle a is greater than zero).

Thus, the sealing member 10 provides a viable seal with bore 26 during relative axial, sliding movement therebetween, relative angular misalignment therebetween, and relative rotation therebetween.

Figures 7 and 8 disclose an alternative embodiment of the invention which has the same basic concept as the embodiment of Figures 1 to 6 the difference being that in the embodiment of Figures 7 and 8 the cylindrical surface with which the sealing mem-

ber is to effect a seal is the exterior cylindrical surface of a cylindrical conduit and the sealing member includes a frustoconical portion having a ring portion at the smaller end thereof, the ring portion fitting around and sealingly engaging the outside surface of the cylindrical conduit. In this instance, the interference fit between the sealing member and the conduit is provided by the minimum free diameter of the curved surface on the ring portion being less than the outer diameter of the cylindrical conduit.

Referring specifically to Figure 7, a tube 70 has a first sealing member 72 at one end and a second sealing member 74 at the other end, both of these sealing members being integrally formed with the tube 70. The first sealing member 72 comprises a frustoconical tapering portion 76 and a ring portion 78 extending from the smaller end of the frustoconical tapering portion 76. The larger end of the tapering portion 76 extends from the end of tube 70.

Similarly, the second sealing member 74 is comprised of a second frustoconical tapering portion 80 and a second ring portion 82 extending from the smaller end of the second tapering portion 80. The larger end of the second tapering portion extends from the end of the tube opposite the tapering portion 76.

Ring portion 78 has a curved surface 84 which engages, in an interference fit, the outer cylindrical surface 86 of a first cylindrical conduit 88 through which fluid under pressure is to flow and which is secured to a rigid structure (not shown).

Similarly, the second ring portion 82 has a curved surface 90 which engages, in an interference fit, the outer cylindrical surface 92 of a second cylindrical conduit 94 through which fluid under pressure is to flow and which is secured to a rigid structure (not shown).

The sealing engagement of the curved surfaces 84, 90 and the respective outer cylindrical surfaces 86, 92 of the conduits 88, 94 is the same as that discussed above with regard to Figures 1 to 6, and therefore will not be discussed again in detail. However, it is apparent from Figure 7 that fluid flowing between conduits 88 and 94 will be prevented from leaking out of the closed system formed by tube 70 and sealing members 72 and 74 by means of the seal formed respectively between curved surfaces 84 and 90 and the outer cylindrical surfaces 86 and 92 of the conduits.

As shown in Figure 7, a cylindrical canister 96, having an inside diameter equal to the outer diameter of tube 70, is welded to the tube 70 along their contacting margins and, since the canister 96 is of thicker material than tube 70, it provides protection from vibrational forces for the tube 70 and its thin sealing members 72 and 74.

As seen in Figure 7, canister 96 has a first open end 98 extending beyond sealing member 72 and receives therein one end of conduit 88, the diameter of the first open end 98 being larger than the outer diameter of the conduit 88.

Similarly, the other end 100 of the canister 96 is also open and extends beyond the end of the second sealing member 74 and receives the end of the second cylindrical conduit 94, the diameter of the second open end 100 being larger than the outer diameter of the second cylindrical conduit 94.

The second cylindrical conduit 94 has, adjacent the end thereof, a first annular portion 102 which is raised slightly above the cylindrical surface 92, and a second annular portion 104 extending from the cylindrical surface 92 at a location which is spaced leftwards of the portion 102 and to the left of the second open end 100 of canister 96, as shown in Figure 7. These first and second annular portions on the cylindrical surface 92 enable unwanted disengagement of the tube 70 and canister 94 due to various vibrational forces encountered by the conduits 88 and 94 to be prevented. While these annular portions 102 and 104 are shown only on conduit 94, they could also be provided on conduit 88.

Figure 8 shows the arrangement of Figure 7 but in a condition in which the axes of the conduits 88 and 94 are misaligned by an angle b due to for example dimensional tolerances or vibrational or other mechanical forces to which the conduits 88 and 94 are subjected. It has been found that a misalignment angle b of up to about 5° can be tolerated by the sealing apparatus and leakage will occur at a very low rate. The interference fit between the curved surface 84 and the cylindrical surface 86 and the curved surface 90 and the cylindrical surface 92 maintains the necessary contact between these parts to maintain the seal during such misalignment.

The embodiment of the fluid-tight sealing apparatus in accordance with the present invention shown in Figure 9 is the same as that shown in Figure 2 except the curved surface 106 of the ring portion 108 has a radius of curvature in longitudinal section which is equal to the radius of the cylindrical bore 26. Thus, the curved surface has a radius of curvature in longitudinal section equal to X/2 as shown in Figure 9.

Whilst the contact stress of the seal interface between the curved surface 106 and the surface of the cylindrical bore 26 is less than the contact stress in the embodiment of Figure 2 since the area of contact is greater, the embodiment of Figure 9 can maintain a contacting seal interface over a wider range of angular misalignment than can the embo-

diment of Figure 2.

Thus, a sealing apparatus as described herein according to the invention is usuable and re-usuable at extreme temperatures or in enviornments subjected to radiation, in which leakage is minimised even when the apparatus is subjected to axial rotational and angular misalignment and movement is lightweight, easy to make and install and which does not require exact tolerances or finely machined contacting sealing surfaces.

WHAT WE CLAIM IS:–

1. A fluid-tight sealing apparatus for sealingly connecting a tube to a cylindrical surface where the tube and the cylindrical surface are likely to be subjected to relative angular misalignment, axial movement and rotation, the apparatus comprising an annular metallic, resilient sealing member comprising a tapering portion and a ring portion which is integrally and coaxially connected to one end of the tapering portion so that the ring portion and the tapering portion are located on opposite sides of a radial plane containing said one end of the tapering portion, the sealing member being coaxially connected, when in use, to the end of a tube so that the tapering portion is disposed between said end of the tube and said ring portion, the ring portion having a curved surface which has a free diameter as herein defined which is different from the diameter of the cylindrical surface whereby when the sealing member is connected to the cylindrical surface so that the curved surface of the ring portion contacts said cylindrical surface, said ring portion is elastically deformed to produce an interference fit between the curved surface of the ring portion and said cylindrical surface which constitutes a fluid-tight seal therebetween.

2. A fluid-tight sealing apparatus according to claim 1, in which said ring portion and said tapering portion have substantially equal longitudinal cross-sectional thicknesses.

3. A fluid-tight sealing apparatus according to claim 1 or claim 2 in which said ring portion is arcuate in longitudinal cross section.

4. A fluid-tight sealing apparatus according to claim 3, in which said curved surface of the ring portion has a radius of curvature in longitudinal section which is equal to or less than half the diameter of the cylindrical surface.

5. A fluid-tight sealing apparatus according to any of claims 1 to 4, in which said tapering portion is frustoconical.

6. A fluid-tight sealing apparatus according to claim 5, in which said cylindrical surface is the interior surface of a bore formed in a body into which the sealing member is inserted to effect said fluid-tight seal, in which said ring portion is integrally connected to the larger end of said frustoconical tapering portion, and in which the free diameter of the curved surfaces of the ring portion is greater than the diameter of the cylindrical surface.

7. A fluid-tight sealing apparatus according to claim 6, in which said curved surface of the ring portion is disposed radially outwards of the frustocone containing the outer surface of said frustoconical tapering portion.

8. A fluid-tight apparatus according to claim 6 or claim 7, in which said sealing member further comprises a frustoconical short portion of which one end is coaxially and integrally connected to the end of said frustoconical tapering portion opposite to said ring portion, and a cylindrical portion which is coaxially and integrally connected to the other end of said frustoconical short portion.

9. A fluid-tight sealing apparatus according to claim 8, in which said body having said bore formed therein has retainer means, mounted on the outer surface of the body which is adjacent the entrance of said bore, for inhibiting accidental removal of said sealing member from said bore once the sealing member is inserted therein.

10. A fluid-tight sealing apparatus according to claim 9, in which said retainer means comprises a member having an arcuate cutout therein for at least partially receiving said cylindrical portion of the sealing member, said arcuate cutout having a maximum dimension smaller than the larger diameter of said frustoconical short portion of the sealing member.

11. A fluid-tight sealing apparatus according to claim 6 or claim 7, in which said sealing member further comprises a cylindrical portion which is coaxially and integrally connected to the end of said frustoconical tapering portion which is opposite to said ring portion.

12. A fluid-tight sealing apparatus according to any of claims 8 to 11, in combination with a tube, in which said cylindrical portion of the sealing member is integral with the end of the tube which is to be sealingly connected to said cylindrical surface.

13. A fluid-tight sealing apparatus according to any of claims 8 to 11, in combination with a tube, in which said cylindrical portion of said sealing member is welded to the end of the tube which is to be sealingly connected to the cylindrical surface.

14. A fluid-tight sealing apparatus according to claim 5, in which said cylindrical surface is the exterior surface of a conduit around which said sealing member is located to effect said fluid-tight seal, in which said ring portion is integrally connected to the smaller end of said frustoconical tapering portion, and in which the free diameter of

said curved surface is less than the diameter of the cylindrical surface.

15. An assembly comprising a tube, a pair of fluid-tight sealing apparatuses as claimed in claim 14, each sealing apparatus being connected to a respective end of the tube, and a pair of conduits having cylindrical exterior surfaces, each sealing apparatus being fitted over the end of a respective one of said conduits so that the curved surface of its ring portion forms an interference fit constituting a fluid-tight seal with the exterior cylindrical surface of the respective conduit.

16. An assembly according to claim 15, in which an open-ended cylindrical cannister is mounted around the tube so that each end of the cannister surrounds a respective one of the conduits and extends beyond the ring portion of the respective sealing apparatus.

17. An assembly according to claim 16, in which ither or both of said conduits has thereon means for inhibiting accidental disengagement of said cylindrical cannister therefrom.

18. A fluid-tight sealing apparatus substantially as hereinbefore described with reference to and as illustrated in Figures 1 to 6, Figures 7 and 8 or Figure 9 of the accompanying drawings.

19. An assembly as claimed in any of claims 15 to 17, substantially as hereinbefore described with reference to and as illustrated in Figures 7 and 8 of the accompanying drawings.

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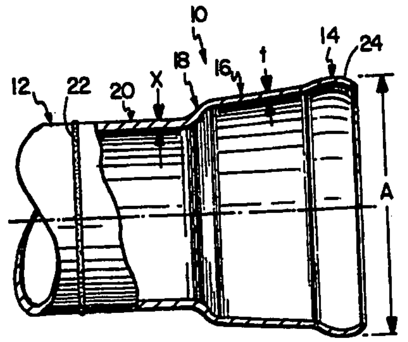

FIG. 1

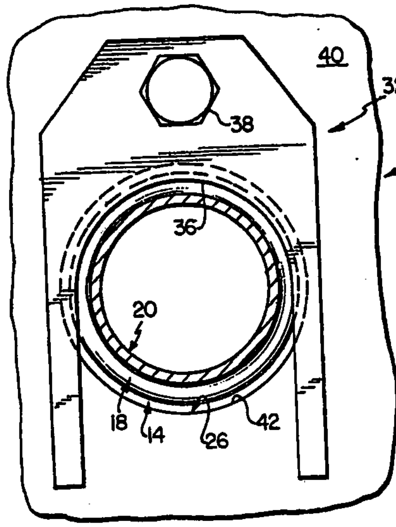

FIG. 3

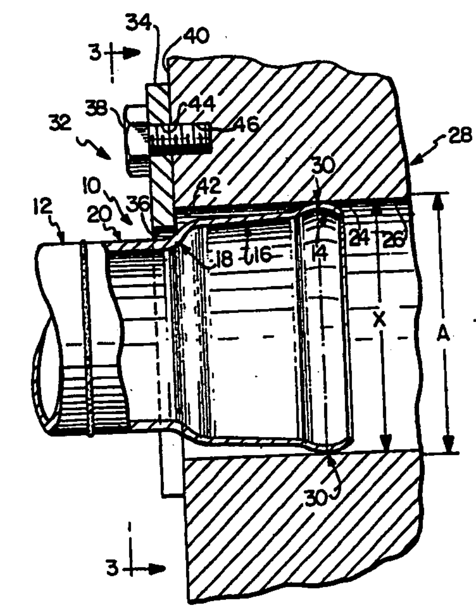

FIG. 2

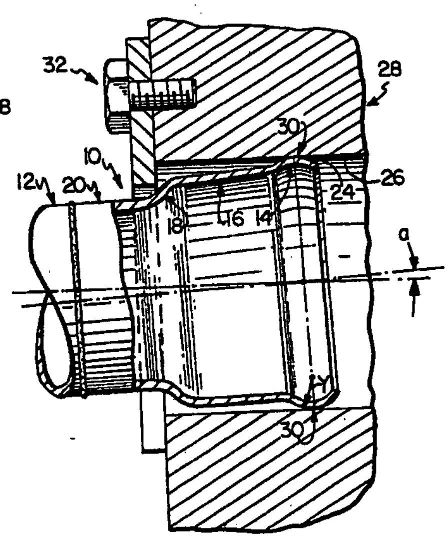

FIG. 4

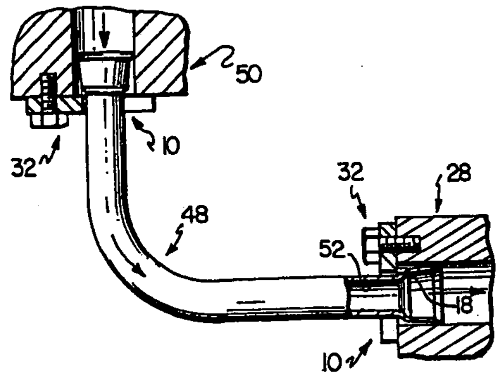

FIG. 5

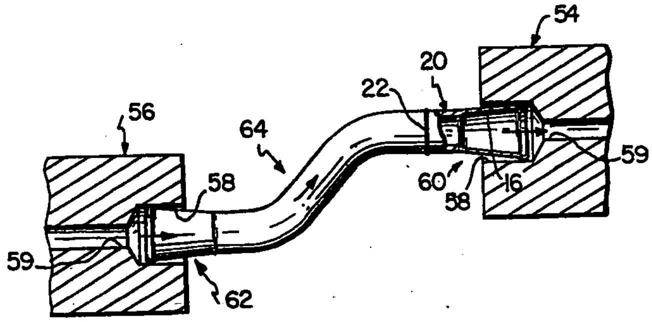

FIG. 6

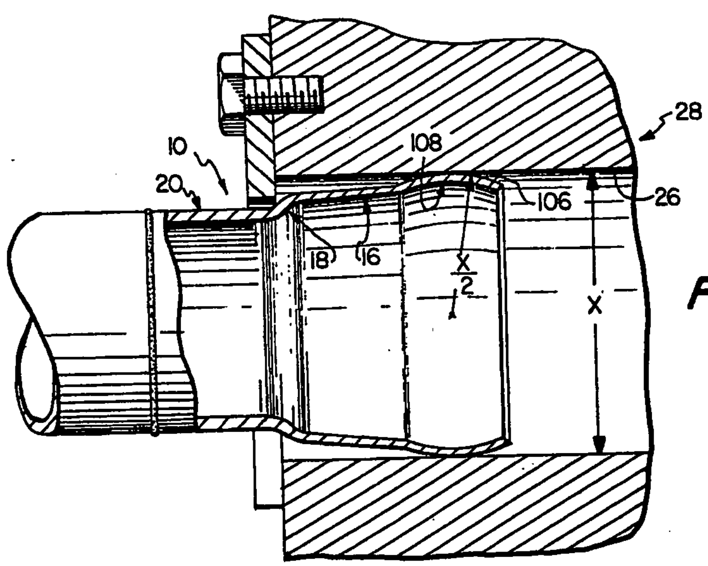

FIG. 9

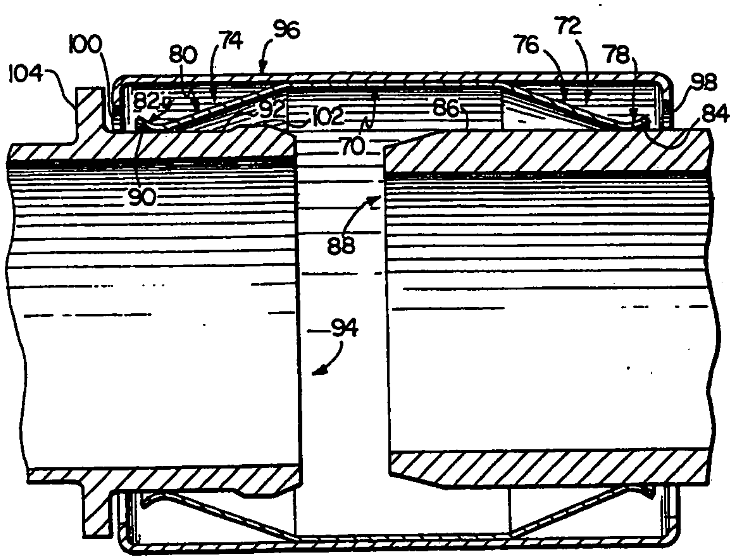
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FIG. 7

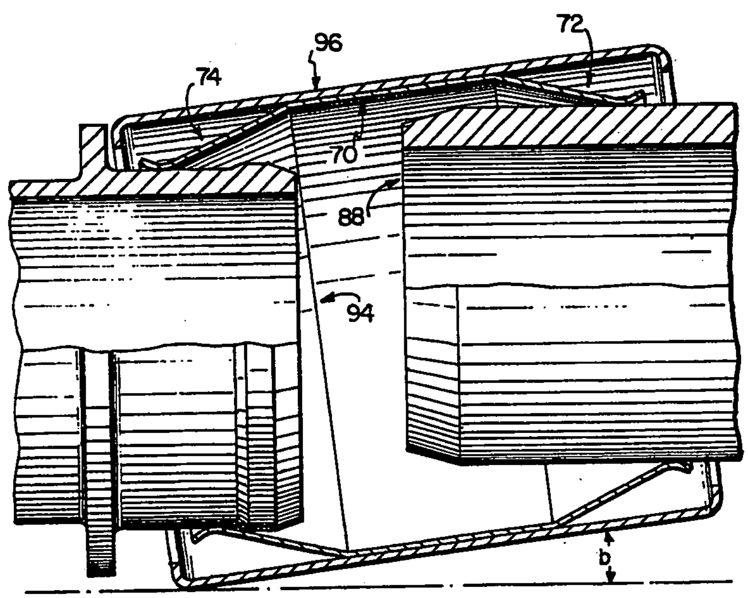
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FIG. 8